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Source: *The Business History Review*, Vol. 69, No. 1 (Spring, 1995), pp. 1-41
Published by: The President and Fellows of Harvard College
Stable URL: http://www.jstor.org/stable/3117119
Accessed: 24/07/2014 15:08

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Mark Clark and Henry Nielsen

Crossed Wires and Missing Connections: Valdemar Poulsen, The American Telegraphone Company, and the Failure to Commercialize Magnetic Recording

The first magnetic recorder, the telegraphone, was invented in 1898 in Denmark. Despite favorable publicity and considerable investment, the telegraphone was a commercial failure. This article uses the theoretical concept of "frames of meaning" to explain that failure, focusing on three factors in particular: Denmark's status as a technologically peripheral country, the telephone orientation of the telegraphone's inventors, and management failures by the firm set up to manufacture the machine.

In the summer of 1898, the Danish telephone technician Valdemar Poulsen invented the telegraphone, the world's first functional magnetic recorder.[1] Aided by the Danish businessman Søren Lemvig Fog, Poulsen set up a research laboratory and a Danish corporation to develop and manufacture machines of his design. The telegraphone, recipient of a gold medal at the Paris Centennial Exhibition in 1900 and widely hailed as a technological marvel, seemed

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[1] A number of inventors in the late 19th century worked with the magnetic recording of sound prior to the invention of the telegraphone, most notably Oberlin Smith of Bridgeton, New Jersey, who published an article in 1888 describing a system essentially identical to that eventually used by Poulsen. However, none of these individuals produced a working machine, and there is no evidence that Poulsen was aware of their work. See Mark Clark, "The Magnetic Recording Industry, 1878-1960: An International Study in Business and Technological History," Ph.D. diss., University of Delaware, 1992, chapter 2.

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destined for success. Over the next twenty years, Poulsen and his partners sought to capitalize on his invention, forming partnerships with firms in Germany and the United States.

Despite the revolutionary nature of his discovery, Poulsen never made a dime from it. The foreign partnerships all failed, and his Danish company eventually went bankrupt. When Poulsen died in 1942, the market for magnetic recorders was tiny, and he was remembered not for his invention of magnetic recording, but for his later work as a radio pioneer. Ironically, within a few years of his death Poulsen's discoveries formed the basis for a major manufacturing enterprise. Magnetic recording is now central to the modern entertainment and computer industries. All of the magnetic recorders in use today, from Walkmen to video recorders to computer disk drives, are based on the principles Poulsen discovered at the turn of the century.

Given the eventual success of magnetic recording, why were Poulsen and his collaborators in Denmark and abroad unable to develop the telegraphone into a commercial product? Most obituaries in newspapers and technical journals after Poulsen's death gave the same answer: Poulsen's invention came "too early." In the eyes of contemporary commentators, the lack of a practical electronic amplifier doomed the device, since the un-amplified telegraphone reproduced its recordings only at low volumes.

In fact, the failure of Poulsen's invention is a much more complicated story. The variety of challenges Poulsen and his collaborators encountered serve to illustrate the difficulties associated with the development and marketing of a radical new invention. Of course, the problems of product development are not unique to the telegraphone. Numerous authors have pointed out the difficulties associated with bringing new technology to the workplace and the marketplace.[2] The primary focus of this literature, however, has been on the cultural and organizational factors that lead groups to reject new technology. In contrast, the problems Poulsen and his

[2] See, for example, Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca, N.Y., 1977); Karell Williams, et al., *The Breakdown of Austin Rover: A Case-Study in the Failure of Business Strategy and Industrial Policy* (New York, 1987); William Lazonick, *Business Organization and the Myth of the Market Economy* (New York, 1991), and "Learning and the Dynamics of International Competitive Advantage," in Ross Thomson, ed., *Learning and Technological Change* (New York, 1993), 172-200; Peter A. Ford, "Charles S. Storrow, Civil Engineer: A Case Study of European Training and Technological Transfer in the Antebellum Period," *Technology & Culture* 34 (April 1993): 271-299.

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collaborators faced were not resistance, (all participants were enthusiastic about the telegraphone and its prospects) but a failure in focus and direction, brought about by the geographic and cultural circumstances associated with the invention's birth.

Three factors are central to an understanding of the telegraphone's commercial failure. First, Poulsen's invention originated in what was at that time a technologically peripheral country. Unable to obtain either sufficient monetary or technical support at home, Poulsen was forced to enter into collaborative agreements with firms in Germany and the United States. Conflict between Danish and foreign interests over money and research direction, coupled with problems of technology transfer, made development difficult and commercialization problematic.

Second, Poulsen, his fellow Danes, and the German firms they worked with were primarily interested in finding some application for the telegraphone within the telephone system. Using a phrase coined by Harry Collins and Trevor Pinch and further sharpened by Bernard Carlson in his study of Thomas Edison's fatal neglect of motion pictures as a mass entertainment medium, we call this orientation of Poulsen and his European collaborators a "telephone frame of meaning."[3] The background experiences in the telephone industry that these men brought with them into the development process handicapped their vision of the new technology, and thus made them unable to develop suitable products and market them efficiently. When their efforts along telephone-oriented lines failed, they gave up and left it to their American partners to exploit Poulsen's invention.

Finally, the directors of the American company, though adhering to a more promising "Dictaphone frame of meaning" in their search for a market for the telegraphone, used inappropriate management techniques as a result of their prior experiences in other manufacturing companies. Thus they were unable to produce a cheap and reliable product that could compete with contemporary dictating machine systems in the marketplace. Although we cannot say for sure that the telegraphone would have succeeded if others had been involved with its development, it is certain that the men who were in charge caused its failure.

[3] W. Bernard Carlson, "Artifacts and Frames of Meaning: Thomas A. Edison, His Managers, and the Cultural Construction of Motion Pictures," in Wiebe E. Bijker and John Law, eds., *Shaping Technology/Building Society: Studies in Sociotechnical Change* (Cambridge, Mass., 1992), 175-200.

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In combination, these three factors ensured that the telegraphone would be a commercial failure. This article details the development of the telegraphone and the impact of these factors.

Inventing and Patenting Magnetic Recording

In the late 1890s, Valdemar Poulsen worked in the technical department of the Copenhagen Telephone Company, and also had regular contact with researchers at the Great Northern Telegraph Company.[4] Poulsen was familiar with the state of the art in both telegraph and telephone technology, and worked as a troubleshooter. In Hugh Aitken's terminology, Poulsen was a "translator" between the scientific, the technological and the economic sphere, and the Copenhagen Telephone Company was one of those focal points where scientific, technological and economic streams of information came together and so was a logical place for innovations to appear.[5]

How did Poulsen become interested in magnetic recording? As he explained later, Poulsen was frustrated by the fact that telephone callers were unable to leave a message if the party they called was not at home.[6] To say that Poulsen felt that the fate of the telephone

[4] Valdemar Poulsen (1869–1942) was born in Copenhagen, the son of a lawyer who eventually became a judge on the Danish Supreme Court. He graduated from the Borgerdydskolen in Copenhagen as a classical student in 1889. He then began the study of medicine at Copenhagen University as his father had wanted, but soon gave it up to read for the entrance examination at the Technical University of Denmark. His difficulties with mathematics prevented him from taking that exam. In 1893 he was hired as an assistant to the chief telephone engineer at the Copenhagen telephone company (KTAS), where in his spare time he invented the telegraphone in 1898. Poulsen left KTAS at the end of 1899. After inventing the arc-transmitter for wireless telegraphy ("The Poulsen Arc") in 1902, he spent the next 20 years developing it into a commercial product. Poulsen served as a member of the boards of the companies created to profit from his inventions, which were patented in most industrialized countries. He received many honors in his lifetime, including an honors degree at the Technical University of Denmark in spite of his inability to pass the entrance examination to that institution! He died in Copenhagen in 1942.

[5] Hugh G.J. Aitken, *The Continuous Wave: Technology and American Radio, 1900–1932* (Princeton, N.J., 1985), 14–17.

[6] See, for example, *Politiken*, 21 October 1899, p. 2, which contains the first Danish newspaper article describing his invention. It is evident that the article was written after an interview with Poulsen.

Telephone answering machines based on phonograph technology were available in the United States beginning in the early 1920s, though opposition by American Telephone and Telegraph limited their use to private telephone systems operated by large firms. The first answering machines using magnetic recording were not offered to the American market until 1953. See Mark Clark, "Suppressing Innovation: Bell Telephone and Magnetic Recording," *Technology & Culture* 34, no. 3 (1993): 521–4, 537.

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Valdemar Poulsen (1869-1942), inventor of the telegraphone, as a young man • (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

rose and fell with the solution to this problem is an exaggeration, but it certainly presented the primary challenge to him in developing magnetic recording. Using telephone components, Poulsen experimented with the application of magnetism to the recording of telephone messages. In the summer of 1898, he discovered that he could record sound using a telephone microphone as an electrical

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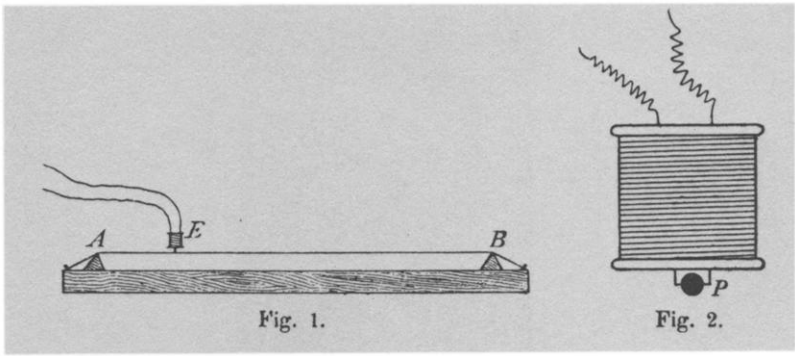

Fig. 1. Fig. 2.

Schematic drawing of the apparatus Poulsen used for his first experiments with magnetic recording • Figure 1 shows a thin steel wire stretched between supports A and B. The electromagnet E is moved along the wire by hand to record or replay sound. Figure 2 is a close-up view of the electromagnet, oriented at a right angle to figure 1. The solid dot labeled P is a cross-section of the steel wire; note that the pole piece of the electromagnet partially surrounds the wire. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

current source which fed through an electromagnet. He was able to make short recordings by moving the electromagnet along a piece of piano wire while talking into the microphone. He could then play back the sound by connecting the electromagnet to a telephone earpiece and moving the electromagnet along the wire at the same speed and in the same direction used during the recording process.[7] Although crude, the device worked, and Poulsen realized that he had discovered a fundamentally new way of recording sound.[8]

By the time of his first patent application on 1 December 1898, Poulsen had built a more sophisticated machine that looked much like Edison's first phonograph. It recorded sound, faintly to be sure, but well enough that Poulsen was able to use it to convince Danish patent authorities and financial backers that he had a working

[7] Poulsen describes this apparatus in his article "Das Telegraphon" in *Annalen der Physik* 3 (1900): 754. An English version of this article is "The Telegraphone: A Magnetic Speech Recorder" in *The Electrician* 46 (1900): 208.

[8] Helge Holst, *Opfindernes Liv*, Vol 2 (Copenhagen, 1915), 239. That August 1898 is the month of Poulsen's invention is confirmed by Absalon Larsen in "Telegrafonen og den Traadlose," *Ingeniorvidenskabelige Skrifter*, No. 2, Teknisk Forlag (Copenhagen, 1950), a book-length Danish-language account of Poulsen's and his partner Peder Pedersen's work on magnetic recording and wireless telegraphy. Absalon Larsen's book contains a wealth of technical and biographical information, a list of Poulsen's and Pedersen's patents by country, and a list of published newspaper and technical journal articles about the two men. Larsen was a retired electrical engineer who had known both inventors well, and he wrote the book at the request of the Association of Danish Engineers to honor "our famous inventor Valdemar Poulsen."

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device. He filed a patent application in Germany on 9 December 1898, eight days after the Danish application. In 1899 he left his job with the telephone company to devote full time to his recorder, which he had christened the "Telegraphone." Between March and May of 1899 Poulsen filed in fourteen more European countries, and on 7 June he applied for an American patent.[9] In those applications, Poulsen included drawings of his phonograph-like recorder and made broad claims related to recording sound magnetically. The text of the Danish application is typical:

> The object of the said invention is a telegraphone, that is an electrical phonograph which will ĩnd its main applications in connection with the equipment employed in modern telephony. The telegraphone can be used locally but is especially useful for distance-phonography, that is recording, storing and replaying speech as delivered from a standard telephone, as the telegraphone in the absence of the called subscriber can substitute for the receiver telephone.[10]

As the above text clearly indicates, Poulsen from the start saw his invention primarily as an extension of the telephone system. Poulsen and his Danish associates would stick to this "telephone frame of meaning" through the first few decisive years of their involvement with the device. This conceptual frame played a guiding role in the attempts to develop and market the telegraphone in Europe prior to 1903.

Poulsen was eventually able to obtain broad protection of the principle of magnetic recording in thirty-eight nations. The subsequent commercial failure of Poulsen's invention was not due to inadequate patents; complete coverage in all likely markets was obtained and these patents were never challenged in court.

Research, Development, and the German Partnerships

Even before the initial Danish patent was granted, efforts were made to exploit the telegraphone commercially. In these efforts, two individuals played an important role. The engineer Peder O. Ped-

[9] Petition to the Commissioner of Patents, June 7, 1899, Patent file for United States Patent #661,619, "Method of Recording and Reproducing Sounds or Signals," United States Patent Office (referred to below as "Patent File"), now in the National Archives, 15.

[10] Danish Patent #2653, 1 (translation by authors).

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ersen was the first to enter the picture.[11] In 1898, while Poulsen was first working on his invention, he met with Pedersen several times for discussions, drawing on Pedersen's superior scientific training. Pedersen became interested in the telegraphone, and began to work with Poulsen in his spare time. Within a few months, the two men formed a partnership, and they continued to work closely together for over twenty years.

While Pedersen contributed technical skills to the endeavor, a Danish businessman, Sren Lemvig Fog, was to become the main force behind the efforts to commercialize the telegraphone.[12] Poulsen and Pedersen probably met Fog not long after Poulsen's invention was first demonstrated to a few of their friends. The exact date of their meeting is not known, but a letter from Fog to Poulsen on March 28, 1899 contains detailed references to the telegraphone,

[11] Peder Oluf Pedersen (1874–1941) was born in the small village of Sig in Jutland, Denmark. The son of a poor farmer, he revealed exceptional interests and abilities in scientific and technical matters at an early age. In 1889, at the age of 15, he conceived of a new kind of engine that would allow irrigation of his father's dry fields with water from a nearby river. Not knowing whom to ask for advice, he wrote a letter to the king of Denmark on the subject! Even though the machine did not work, the letter nevertheless changed Pedersen's life in a dramatic way. He was given a royal stipend allowing him to commence studies at the Technical University in Copenhagen. During his time there he lived in the house of S.C. Borch, a docent at the university. He was introduced to a number of the people who eventually would have great influence on his life. Among these were Marie Lihme, later to become his first wife, Valdemar Poulsen and Søren Lemvig Fog. Pedersen graduated from the Technical University with a degree in civil engineering in 1897. In the years from 1899 to sometime around 1920 he collaborated with Valdemar Poulsen on the development of the telegraphone and the Poulsen Arc, an early radio transmitter. In 1909 he became docent at the newly established Institute of Telegraphy and Telephony at the Danish Technical University, 1912 professor at the same institute, and from 1920 until his death in 1941 he was the director of the Technical University. During his lifetime, Pedersen published a large number of scientific articles, mainly on the theory of the Poulsen Arc and on the generation and transmission of radio waves.

[12] Søren Lemvig Fog (1863–1906) was born in Aalborg, Denmark, the son of a customs agent. He originally trained as an officer, but left that career after he authored a series of articles for the Danish newspaper *Politiken* that were critical of the Army. He went to Brazil some time around 1887. He first set up a match factory, and then invested in a paper mill and various agricultural projects. Fog benefited from the economic boom that followed the establishment of the Brazilian Republic. During the revolutionary period in that country during the early 1890s he turned to the import business, selling war material and railway equipment to the Brazilian government. After making his fortune on a series of large deals (for example, he imported four naval cruisers from Germany to fulfill one contract), he returned to Denmark in the mid-1890s as a wealthy man.

Fog had a reputation for being flashy, especially among other Danish businessmen, since he often gave elaborate parties and always entertained guests in lavish style. He also had a reputation for involving himself with businesses that combined "Danish skill and American smartness." Surviving correspondence shows that Fog saw the telegraphone as a potential example of this sort of business, and that he developed a close personal relationship with Poulsen as a result.

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Peder Pedersen (1874–1941), Poulsen's collaborator, in later life • (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

and it is clear that their relationship was well established at that point.[13] It is also clear that Fog in early 1899 had begun to press Poulsen and Pedersen to develop commercial applications for their machine, and that he was working hard to interest investors in the telegraphone.

In the summer of 1899, Fog succeeded in establishing Aktieselskabet Telegrafonen-Patent Poulsen, a Danish corporation. The company took over Poulsen's patent rights in exchange for shares in

[13] Fog to Poulsen and Pedersen, March 28, 1899, P.O. Pedersen Archive, History of Science Department, Aarhus University, Aarhus, Denmark. This archive contains most of Pedersen's surviving correspondence and other personal papers, including his notebooks and diaries. Poulsen's papers have not been located, and apparently were lost after his death.

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the firm.[14] Poulsen and Pedersen resigned from their jobs, Poulsen becoming the firm's director and Pedersen the chief engineer. By the end of 1899, the staff was expanded to include one more engineer, E. S. Hagemann, the electrical technician J. P. Christensen, and the skilled machinist E. Lübcke. The latter two individuals were in charge of actually building the experimental apparatus for the three engineers, while Hagemann was an assistant to Pedersen and Poulsen.

The board of Aktieselskabet Telegrafonen soon found that they needed additional help to commercialize the telegraphone. From later events we know that Poulsen, rather optimistically, thought he and his small technical staff could develop the telegraphone into a marketable product, but Lemvig Fog and the rest of the board disliked that idea.[15] They had invested in the telegraphone to earn money as quickly as possible, and thus they wanted collaboration with a company that had sufficient technical expertise to offer a speedy development of the telegraphone and that was big enough to market the product over most of Europe. The question was, whether were there any serious Danish candidates for this task. The answer must have been rather obvious to the board, if not to Poulsen and Pedersen: there were none.

Although Denmark was industrializing rapidly around the turn of the century, most Danish firms were still quite small by European standards. Danish industry was primarily oriented towards the domestic market, only about 10 percent of its production being exported in 1897.[16] As a result, Denmark, with its small and still primarily agricultural economy, was dependent on foreign countries for most industrial goods and services. It is certainly true that some Danish industrial companies were successful on the international market. The firms of Carlsberg (beer), F.L. Smidth (cement), Burmeister and Wain (shipbuilding), and the East Asiatic Company (trading) are good examples, but they were few in number and competed only in niche markets.

Moreover, there were strong voices—even among industrialists—warning against the evils that were supposed to accompany any large scale industrialization of Denmark along the lines of England,

[14] The company was capitalized at two million Danish kroner, at that time roughly equal to half a million American dollars.

[15] Pedersen to Lunn, 4 August 1900; Poulsen to Lunn, 6 August 1900, P.O. Pedersen Archive.

[16] Svend Aa. Hansen, *Økonomisk vækst i Danmark, I* (Copenhagen, 1976), 230.

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Germany and the United States. The chairman of the influential Københavns Industriforening (The Industrial Association of Copenhagen), Mr. Philip Schou, was one of those who warned against too much industry. Stressing Denmark's poor prospects as an industrial nation, since it had no raw materials such as coal or iron within its boundaries, he was very much in favor of Denmark's proceeding along a separate road towards a prosperous future. He felt Danish industry should attempt to create a unique blend of art, craft and industry, rather than follow the lead of other nations. In 1888, in his official speech at the society's 50 year anniversary, Schou claimed that "our people are probably not fit for building an industrial nation, used as they are to finding their food on our fertile plains." Schou was not alone in his opinions: in 1890 the well-known Danish national economist Scharling concluded that "of new and spectacular industrial firms there are only a few to be mentioned."[17]

For the industry of most relevance to the commercialization of the telegraphone, the situation was no better. Partly as a consequence of tariff laws that favored the import of finished products over the import of raw materials, the Danish electrotechnical industry was very small, and most electrical equipment was imported. As late as 1907, just before the tariff laws were changed to favor domestic manufacturers, it was estimated by a leading Danish electrical engineer that 80 percent of the dynamos, electric motors and electrical equipment installed in Denmark that year had been imported.[18] Although Danish communications firms, such as the Great Northern Telegraph Company and the Copenhagen Telephone Company, were as sophisticated in operation as their foreign counterparts, they focused on the design and operation of their networks, not on manufacturing. Both of these companies did have elaborate repair shops, but most of their new equipment came from Denmark's great southern neighbor, Germany. The main suppliers were the firms of Siemens & Halske, AEG, and Mix & Genest.[19]

[17] William Scharling, "Københavns udvikling og fremtid", in *Nationaløkonomisk Tidsskrift* (1890), 10.

[18] C. Hentzen, "Hvilken Betydning har den nye Toldlov for den danske Elektrotekniske Industri?" in *Elektroteknikeren* (1910), 2–7.

[19] For more details on the Great Northern Telegraph Company and its success in the international telegraph communication traffic, see H. Nielsen and M. Wagner "Technology in Denmark" in Jan Hult and B. Nyström (eds.) *Technology & Industry—A Nordic Heritage* (Canton, Mass., 1992), 16–17. The authoritative sources for Great Northern's

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Because there were also strong cultural ties between the two countries (most well-educated Danes spoke German and read German books), it was natural that Aktieselskabet Telegrafonen would turn to Germany to find a partner with the expertise to develop and market a commercial product. The partner they selected was the firm of Mix & Genest, a major German manufacturer of telephone and telegraph equipment.[20]

The firm supplied telephone equipment to the Copenhagen Telephone Company, so Poulsen would have been familiar with their products. Moreover, Mix & Genest had its own research laboratory. The German firm seemed to be an ideal partner for further development work on the telegraphone.

During the winter of 1899 an informal agreement was reached between Mix & Genest and Aktieselskabet Telegrafonen. The agreement itself does not survive, but we do know that one result of its signing was the transfer in early May 1900 of most of Aktieselskabet Telegrafonen's technical staff to Berlin to work at the Mix & Genest research and development department. Their initial task was to design and build machines for exhibit at the Paris World Exhibition in June 1900.

The Paris Exhibition

Displaying their invention at a world exhibition was a logical strategy for Poulsen and his collaborators. Ever since the Crystal Palace Exposition of 1854, world exhibitions had provided places where innovative technologies could be exposed to the widest possible audi-

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history prior to 1886 are Ole Lange's *Finansmaend, Straamaend, og Mandariner* (Copenhagen, 1978), and *Partnere og Rivaler* (Copenhagen, 1980).

[20] The firm Mix & Genest was set up as a mechanical workshop in Berlin in 1879, but was incorporated and renamed in 1889 as Mix & Genest, Telephon- und Blitzableiterfabrik, Inc. In 1899 the company became Mix & Genest, Telephon- und Telegraphenwerke, Inc., the president and general manager being the engineer Werner Genest. The company's main quarter was in Blowstrasse 67, Berlin, but around the turn of the century the company operated branches in Cologne, Hamburg, London, Glasgow, Amsterdam, and Moscow. At the turn of the century the total number of employees was close to 1700 and the capitalization was 3.6 million Marks. Mix & Genest was purchased by Standard Elektrik Lorenz in the 1930s and was merged in 1954. Saling's *Börsen Jahrbuch* 1901–02, 2. Teil; *Handbuch der Deutschen Aktiengesellschaften* (1938), 6977–79 and (1961), 1946–47.

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ence.[21] Poulsen was no doubt aware of the favorable publicity that could be generated. Active as he was in the telephone industry, he surely would have been familiar with Alexander Graham Bell's dramatic demonstration at the American Centennial Exposition in Philadelphia in 1876. More recently, Thomas Edison had shown off his electric light at the 1881 Paris Exhibition and his phonograph at the 1889 Paris celebration of the centennial of the French Revolution. George Westinghouse demonstrated his new alternating current electrical power system to wide acclaim at the Columbian Exposition of 1893.[22] In all of these cases, the inventors were conscious of the power of exhibitions to publicize and legitimize their inventions, and they spent a lot of time and effort in preparation for them. The potential rewards were great—new investment, the opening of overseas markets, and the creation of consumer demand for their products. No doubt Poulsen and his collaborators hoped the telegraphone would achieve similar recognition.

In preparation for their debut in Paris, Poulsen, Pedersen, the technician Christensen and the machinist Lübcke stayed in Berlin until early June, working daily with Mix & Genest's engineers and technicians, most notably H. Zopke and Ernst Ruhmer.[23] They worked to improve their existing cylinder telegraphones and also initiated the development of several new designs in an attempt to improve sound clarity and volume, including a reel-to-reel machine using steel tape or wire to replace the old cylinder model. Work on these included the use of different wire or tape dimensions, different recording head configurations, and variations in transport speed.

In the course of these experiments the team experienced at least one definite success, the discovery that a recording can be substantially improved by means of DC-biasing.[24] The discovery was made on 14 or 15 May 1900 during a series of systematic attempts to improve the quality of sound recorded on a new steel tape machine. In each run a brief message was recorded on the tape, then replayed, judged for quality, and finally erased by a strong erasing magnet.

[21] Eugene S. Ferguson, "Expositions of Technology," *Technology in Western Civilization: The Emergence of Modern Industrial Society—Early Times to 1900, Vol. 1* (Oxford, 1967), 706–726.

[22] Ibid., 725; Andre Millard, *Edison and the Business of Innovation* (Baltimore, Md., 1990), 118–21.

[23] P.O. Pedersen diary, 1900. The diary covers the period from 1 May (the day of Pedersens arrival) to 7 June (the day before he left for Paris), and is currently in the P.O. Pedersen Archive.

[24] U.S. patent 873,083 of 1907. The application was filed on 12 June 1902.

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Thus the tape was left in a state of maximum transverse polarization (remnant magnetism) before each new run. What Poulsen and Pedersen discovered was that the quality of the recording was substantially improved if the recording magnet was subjected to a DC-current in addition to the signal current from the microphone, the DC-current causing a constant polarization in the opposite direction of the one caused by the erasing magnet. The subject was taken up for further investigation on 28 May 1900, and from the description in the diary it is evident that Pedersen was aware that he and his colleagues had made an important discovery.[25] DC-biasing leads to a considerable improvement in sound quality, and was standard in all magnetic recorders until the early 1940s, when it was replaced by the superior AC-bias technique.

Poulsen's assistant Hagemann was also involved in his own research on the possibility of using the telegraphone as an amplifier. Hagemann's amplifier used a drum provided with a series of steel rings having their centers in the axis of the drum and their plane of orientation perpendicular to it (see figure 2). The signal to be amplified is recorded on the first ring as it rotates. The recording is then re-recorded onto the other rings in succession by copying from the first ring. The record on all the rings used to re-record will be the same strength, since the current in each recording electromagnet is the same. In principle, the device would then play back all of the recordings simultaneously into the same circuit, producing a current identical to but stronger than the original input signal, provided the number of rings is sufficiently large.[26] In practice, however, each additional added signal adds noise as well as volume. Moreover, any slight misalignment of the playback coils meant that the components of the output signal would be out of phase with one another, adding more noise. As a result, the signal-to-noise ratio quickly increases to the point where the output, though louder, can no longer be understood. This problem was not immediately apparent, however, and when the telegraphone was demonstrated in Paris, both DC-bias and Hageman's amplifier idea were central to Aktieselskabet Telegrafonen and Mix & Genest's sales pitch.

The exhibition in Paris in the Summer of 1900 was a major international industrial gathering. It provided the first opportunity

[25] Pedersen underlined the key sentences, something quite unusual for him. The advantages of using DC-bias in magnetic recording was, as far as we know, first mentioned in the article by Valdemar Poulsen, "Das Telegraphon", *Annalen der Physik* 3 (1900): 754–60.

[26] Danish patent no. 3629, 29 December 1900.

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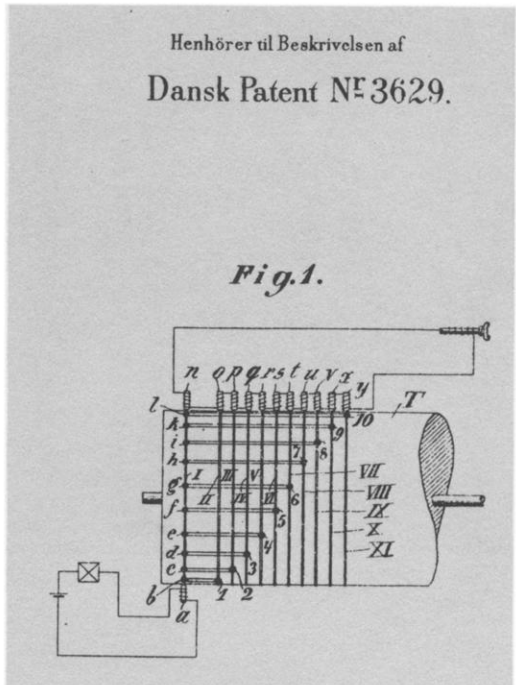

Drawing from Hagemann's amplifier patent application, showing the connections required to produce amplification • The electromagnet a (shown at the lower left) makes the original recording on wire I. The electromagnets b through l pick up that recording and re-record it on wires II through XI using electromagnets 1 through 10. The electromagnets n through y pick up the eleven resulting recordings simultaneously and transmit the signal to the speaker shown at the upper right of the drawing. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

for Aktieselskabet Telegrafonen and Mix & Genest to expose their telegraphone to a large audience, and they planned to make the most of it. At the exhibition, Aktieselskabet Telegrafonen constructed a small but elaborate kiosk in the section devoted to Danish Industry. There the company demonstrated several machines of the cylinder type for the public.

Mix & Genest also exhibited their improved telegraphones in Paris, but not to the public. The company held private demonstrations for invited guests, including reporters from the technical press. At these demonstrations, Poulsen and Pedersen were usually responsible for the operation of the equipment. For Pedersen at least, these demonstrations caused real anxiety. After the excitement of the first few days, he began to show signs of strain, and in letters to his wife he complained of "bad nerves" and even contemplated leaving

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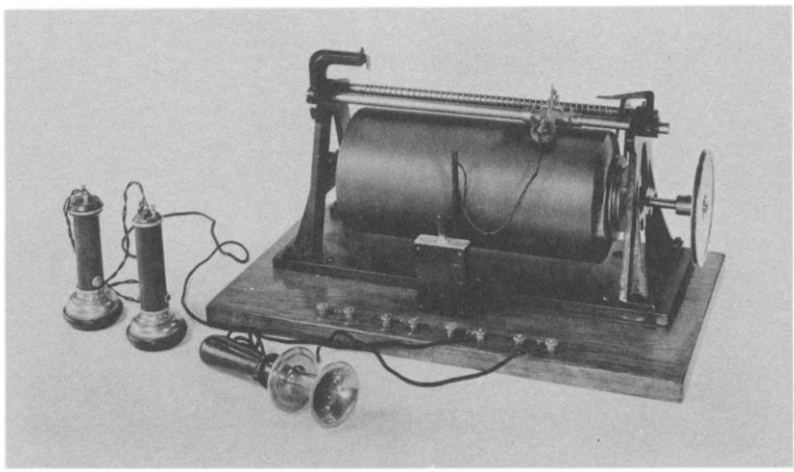

Photograph showing a Poulsen cylinder type telegraphone from 1898, similar to the machine demonstrated at the Paris exhibition in 1900 • The non-magnetic cylinder has a thin steel wire (diameter approximately 1 mm) wound around it in a spiral pattern. The recording head moves parallel to the axis of the cylinder on a threaded rod, tracking the wire on the cylinder as it rotates. The length of the cylinder is 28 cm, its diameter 14 cm. The wire, approximately 100 m long, can store a message of 45 seconds duration. The machine is now at the Danish Technical Museum, Elsinore. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

his position with the company.[27] He managed to survive the experience, however, and at the end of June, when the demonstrations were finished, he returned to Berlin.

Pedersen and Poulsen's efforts during the demonstrations, as well as the work of Fog and Mix & Genest, paid off. The telegraphone was the hit of the exhibition, and it received a great deal of publicity and a Grand Prix from the exhibits committee. A number of prominent individuals examined the machine, including members of the Siemens family and the novelist Emile Zola.[28] Poulsen and Fog even managed to interest the Emperor Franz Joseph in their machine; the Austro-Hungarian ruler consented to make a short recording. Presently preserved at the Technical Museum of Vienna, it is the oldest surviving magnetic recording in the world. Poulsen no doubt sought to emulate Alexander Graham Bell, who had induced the Brazilian Emperor Dom Pedro to use his newly-invented telephone twenty-four years before at the American Centennial Exposition in Philadelphia.

[27] P.O. Pedersen to Mrs. Pedersen, 18 June 1900, P.O. Pedersen Archive.

[28] The guest book used at the exhibition is in the collection of the Danish Technical Museum, Helsingor, Denmark.

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More importantly for the future success of the Danish firm, a stream of technical articles appeared over the next few months in professional journals, describing the telegraphone and singing its praises.[29] All of the articles stressed the many possible applications of the telegraphone (as telephone answering machine, as a means for reporting news to telephone subscribers, as dictating machine), but it was the applications related to the telephone that received the most attention, thus giving support to Poulsen and his collaborators' telephone frame of meaning. One typical example is the article on the news at the Paris Exhibition, written by John Gavey, who was later to take over the prestigious position as chief engineer of the British Post Office.[30] The section on what he called "Poulsen's Microphonograph" was introduced by the statement: "Perhaps the invention of the greatest scientific interest is the Poulsen Microphonograph, by which a telephone conversation can be permanently recorded on a steel wire, and reproduced at any time".[31] Next followed a detailed description of the various functions of the apparatus, before the writer summed up his own judgment of its future prospects:

> At present this invention is in the early stage of scientific discovery. It may be used by a telephone subscriber to record an important communication, and it promises to afford means of obtaining a telephone repeater, a problem which has been before the electrical world for the last twelve years, and which so far has not been solved in a satisfactory manner. A telephone repeater would increase the range of telephonic speech and decrease the cost of long lines. The President of one of the American telephone companies some time ago offered publicly a reward of 1,000,000 dollars for a thoroughly satisfactory telephone repeater, but the money has not yet been earned.[32]

As is evident from this quotation, Hagemann's idea of using the telegraphone as an electrical amplifier had caught the imagination of writers familiar with the telephone industry. No practical electronic

[29] See, for example, J.H. West: "Rundschau" in *Electrotechnische Zeitschrift*, 17 May 1900 and 21 February 1901; J.Blondin, "Telegraphone Poulsen" in *L'Eclairage Electrique*, 16 June 1900; V. Poulsen, "Sur le telegraphone" in *Comptes Rendus*, 25 June 1900, 1754; H. Zopke: "Die Weltausstellung in Paris" in *Annalen für Gewerbe und Bauwesen*, 1 August 1900, 55; J. Gavey: "Poulsen Mirrophonograph" in *Journal of the Institution of Electrical Engineers* 30 (1900): 88; W.J. Hammer: "Important European Electrical and Engineering Developments at the Close of the Nineteenth Century" in *Transactions of the AIEE* 18 (1902): 47.

[30] Gavey, "Poulsen Mirrophongraph," 88.

[31] Ibid.

[32] Ibid., 89.

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amplifier existed at the time (the vacuum tube was still some years away), so any invention related to telephone amplification was hailed as a potential breakthrough. It appears that the telegraphone amplifier concept, which was not actually demonstrated at the exhibition, accounted for a good deal of the extensive press coverage. This is most clearly seen in the fact that, when subsequent tests showed that Hagemann's idea was unworkable as an amplifier, the interest of the technical journals in the telegraphone declined markedly.

Conflict in Germany

After returning from Paris, the researchers turned to developing a commercial machine. The primary focus was on improving the circuitry used to connect the telegraphone to the telephone network. Despite some progress, there was increasing tension between Mix & Genest and their Danish partners, owing to the slow pace of development. This tension was aggravated by the continued lack of a firm agreement between Mix & Genest and Aktieselskabet Telegrafonen. Soon after the return from Paris, the first signs of disagreement and rivalry surfaced, disagreements that would eventually lead to the termination of cooperation between the two firms.

As related above, Pedersen felt both physically and mentally exhausted from his time in Paris. He obtained what he thought was permission from Lemvig Fog to go on an indefinite holiday to recover his health, and departed for Copenhagen a few days after returning from Paris. He and his wife then went to stay with his parents in rural Jutland, the Danish mainland. Pedersen "forgot" to inform Mix & Genest about his holiday plans, and did not leave them his address.

His absence was soon noticed in Berlin, and was not appreciated. Mix & Genest sent curt letters demanding his return, first to his hotel in Berlin and then to his home in Copenhagen.[33] These letters triggered a heated exchange between August Lunn, treasurer and member of the board of Aktieselskabet Telegrafonen, and

[33] Mix & Genest to Pedersen, 11 July 1900 and 17 July 1900, P.O. Pedersen Archive. Poulsen was also in Denmark at this time. It is unknown if he received a similar letter, but it seems likely.

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Poulsen and Pedersen about the research project, an exchange that soon grew to include the management of Mix & Genest.[34]

The conflict between the Danes and the Germans arose from the divergent views they held about how to reach the goal of a commercial machine. Poulsen and Pedersen felt that considerable basic research work remained to be done before the telegraphone would be ready for service under field conditions. Managers at Mix & Genest, on the other hand, wanted a commercial product as soon as possible, and were unwilling to spend money on further work unrelated to producing a marketable machine. This conflict had not surfaced before, because the two firms had concentrated on building an apparatus for exhibit in Paris. Once that task was complete, Mix & Genest immediately gave their highest priority to the recording and playback of real telephone conversations. The technicians of the firm had done work along these lines since Pedersen's departure from Berlin, but without positive results.

Poulsen and Pedersen were recalled to Berlin. After examining the German engineer's notes and experimental set-up, the two men explained Mix & Genest's failure as being the result of an overly ambitious and poorly planned series of experiments. Poulsen and Pedersen claimed that they had successfully resolved most of the German's problems in a recent series of experiments that had yielded clear and understandable speech, but they warned Mix & Genest that in the future they did not want to be associated with experiments that they had not developed themselves.[35] It appears that this comment precipitated the final split between Mix & Genest and Aktieselskabet Telegrafonen. The formal ending of the collaboration happened some time around the end of August, 1900.

Pedersen's diary as well as letters exchanged between the Danes and the Germans during the Mix & Genest period indicate that a deep-rooted mistrust between the two parties was the cause of the separation. The Danish researchers had quickly gotten the impression that they were undervalued by the German technicians, who did not want to take advice from the Danes. Whether this impression

[34] Lunn to Pedersen, 2 August 1900, and 6 August 1900; Pedersen to Lunn, 4 August 1900; Poulsen to Lunn, 6 August 1900; Lunn to Pedersen, 11 August 1900; Lemvig Fog to Pedersen, 11 August 1900, P.O. Pedersen Archive.

[35] Poulsen and Pedersen to Mix & Genest, 22 August 1900. P.O. Pedersen Archive. It is clear from this letter that Poulsen and Pedersen did not attempt to record telephone conversations over more than one exchange. As later tests would show, the recording of long-distance calls established via more exchanges was much more difficult, and in fact was never solved by the Danes or their German collaborators.

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was true or whether the Danes just suffered from an inferiority complex is not clear, but it is indisputable that Poulsen and his associates did not feel very welcome in Berlin. For example, Poulsen and Pedersen were humiliated by having to beg Mix & Genest for salary and travel money to be able to go to Paris.[36] It is also significant that not a single technical article co-authored by Danish and German researchers was published as a result of the collaboration, in spite of the fact that the Danes as well as the Germans published substantially during the year 1900.

After the break with Mix & Genest, Lemvig Fog, the head of the Danish firm, began a search for new partners. He visited the United States in early 1901, and he contacted a number of German firms. His visit to the United States proved unsuccessful, but in the spring of 1901 Fog reached an agreement with the prominent German firm Siemens & Halske (ancestor of the current Siemens company). Siemens & Halske purchased the rights to produce telegraphones in Germany, Austria-Hungary, and Russia. During the first few months of the agreement they were very optimistic about the prospects for the telegraphone, but by early 1902 their attitude had turned sour. Unable to develop a lighter and simpler telephone answering machine with better sound quality despite considerable investment, Siemens & Halske canceled their agreement in April 1902, claiming that the volume of reproduction was unlikely to become much better "unless a new way is found to fulfill this goal." Siemens & Halske's move represented a serious blow to the telephone frame of meaning.[37]

The failure of both German joint ventures illustrates the problems caused by Denmark's status as a technologically peripheral country. Owing to a lack of domestic resources, Poulsen and his associates were at the mercy of the interests of the German firms they dealt with. The Danish group's inability to dictate the course of research and development led to constant friction and delay. Poulsen and Pedersen's frustration with their lack of control over progress appears to have played a large role in their decision to abandon the telegraphone in favor of radio research in early 1903.

[36] Pedersen diary, 1 June 1900, P.O. Pedersen Archive.

[37] Lunn to Siemens & Halske, 28 April 1902, Siemens Archive, Siemens Museum, Munich, Germany.

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A New Danish Strategy

Since the technological world view of the leaders of Aktieselskabet Telegrafonen was strongly dominated by a telephone frame of meaning, the network of patents, technical experts, investors, economic advisors, and foreign collaborators which was set up to explore the invention was molded by telephone ways of thinking. The effort was focused on producing a product suitable for use within a telephone system. Not surprisingly, the network proved to be fragile when it turned out to be much more difficult to develop a reliable telephone answering machine than had been imagined. Moreover, Hagemann's telephone amplifier concept, which in the beginning created a wave of optimism, also proved unworkable. These failures caused the collapse of the Danish development network; the German collaborators withdrew, and the Danes were left alone again.

The unsuccessful ventures in Germany and the ongoing but seemingly endless negotiations with American investors led the Danes to set up their own development and production company, Dansk Telegrafonfabrik, in 1903. The Danish telegraphone factory over the next few years developed two different types of telegraphones, a simple disk type with a recording time of approximately 2 minutes and a much more complicated wire type with a recording time of about 30 minutes.

Both were designed as dictating machines, indicating a significant change in orientation among those behind the attempts to commercialize the telegraphone. Even Valdemar Poulsen had changed his mind after two years of unsuccessful efforts to develop a telephone answering machine together with technicians at Mix & Genest and Siemens & Halske. In 1903 he admitted that:

> According to its basic principle the telegraphone seems destined to find its place in large administrative departments with the purpose of recording telephone conversations, in small offices it should also be very useful for leaving and receiving messages when nobody is present. . . . As the telephone companies of various countries tend to be rather different, technically as well as with respect to service, it is usually not possible to use the same type of telegraphone everywhere; certain changes in the electrical circuit and in the mechanical releasing mechanism will be necessary. Therefore I believe that the applications of the telegraphone outside telephony will come first.[38]

[38] Valdemar Poulsen, "Telegrafonen", *Fysisk Tidsskrift* 2, (1903): 33.

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Danish disk type telegraphone, built in the period 1905-09 when E. Hytten was director of Dansk Telegrafonfabrik in Copenhagen • The disk is 0.5 mm thick and 130 mm wide steel plate, rotating by means of a clockwork drive. The velocity of the disk relative to the reading/writing head is 0,5 m/s. (Photograph courtesy of the Danish Museum of Science and Technology.)

The Danish production company only manufactured a small number of these machines. Exactly how many telegraphones were built in Denmark to Poulsen's design is unknown, but the number was small, probably fewer than 200.[39]

The absence of a clear market strategy and the fact that Poulsen and Pedersen had left the magnetic recording field to concentrate on Poulsen's new inventions within wireless telegraphy account in part for this limited production. But the primary reason was that Dansk Telegrafonfabrik—which employed only a handful of people—was never meant to be a factory for any large scale production of telegraphones. It was a precision workshop, set up to manufacture the delicate equipment needed by Poulsen and Pedersen in their increasingly successful work on wireless telegraphy, and—just as important—to improve the bargaining position of the Danes in the ongoing negotiations with American investors.

[39] The highest surviving serial number of a telegraphone built by the company is 121, and it is unlikely that many more were built. The machine is in the collection of the Danish Technical Museum, Elsinore. The figure 200 is from "Depositions by Valdemar Poulsen and Jacob Tesdorph," Court Hearing on the Extension of Patent, The High Court of Justice, Chancery Division, Public Record Office (London, 1913), 6.

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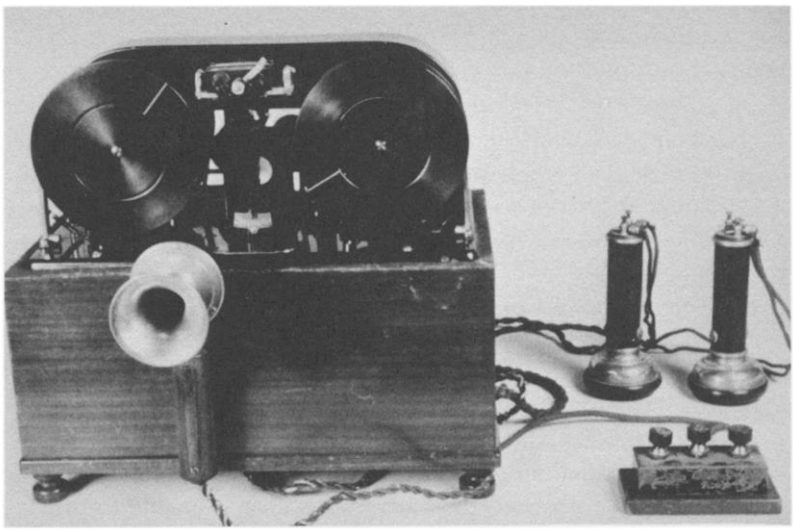

Wire type recording telegraphone, built in the period 1905-09 when E. Hytten was director of Dansk Telegrafonfabrik in Copenhagen • The machine uses 0.25 mm thick steel piano wire as a recording medium, driven by a direct current electric motor. The velocity of the wire is 2-3 m/s with respect to the reading/writing head. (Photograph courtesy of the Danish Museum of Science and Technology.)

Negotiations with American Investors

The first Danish delegation to the United States actually had been sent in January of 1901. The delegation consisted of Søren Lemvig Fog, the Chairman of Aktieselskabet Telegrafonen's board, Jacob Tesdorpf, a major shareholder and friend of Fog, and the two technicians, E.S. Hagemann and J.P. Christensen. Because of the publicity from the Paris exhibition and the contacts they had made there, Fog and Tesdorpf had no trouble in making contacts with interested American investors, including representatives of the Bell Telephone Company and men who had financed Edison's inventions.[40] The delegation spent most of its time over the next few months meeting with investors and demonstrating the machines. In their spare time, Hagemann and Christensen actively experimented with recording and playing back messages over the American telephone system, yet

[40] Our knowledge of the Danish delegation's travel to the United States in early 1901 is primarily based on letters from Fog and Hagemann to Poulsen and Pedersen in Copenhagen. The letters are in the P.O. Pedersen Archive.

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another example of the telephone focus of the Danes before 1903.[41]

After long and difficult series of negotiations, an agreement was reached in March 1903.[42] The agreement formed the basis for the incorporation in September 1903 of the Telegraphone Company of Maine. This firm served as a holding company for the worldwide telegraphone patents, and was entirely owned by Danish investors. The American Telegraphone Company, incorporated in the District of Columbia in October 1903, assumed the ownership of all American patents on the telegraphone. The District of Columbia company was capitalized at $5,000,000, and almost all the shares were owned by the Telegraphone Company of Maine, giving the Danes effective control. The central figure at American Telegraphone was the lawyer John Lindlay, who over the next two years made energetic but ineffective attempts to obtain venture capital for the establishment of a factory. Lindlay and his fellow American investors were willing to commit the small sums needed to form the corporations in the hope of future profits, but they were unwilling or unable to provide any large sum of money for the development of the telegraphone. The Danes, on the other hand, expected the Americans to raise the money needed and were unwilling to invest any cash. So matters stood until 1905, when a new actor entered the scene.

In the summer of 1905, Lindlay met Charles Fankhauser, an American broker and investor who offered to act as agent to sell American Telegraphone shares to the public.[43] Fankhauser persuaded the Danes to transfer a majority holding of their stock from the Maine corporation to the American Telegraphone Company's own treasury in exchange for a small cash payment. This gave the board of directors of American Telegraphone direct control over their company, since the Danes were now effectively minority shareholders.

[41] These experiments were similar to those carried out in Europe during the previous year and involved primarily recording long-distance conversations. Hagemann to Pedersen, 31 January and 24 February 1901; Fog to Pedersen and Poulsen, 24 February 1901, P.O. Pedersen Archive.

[42] Agreement between Lemvig Fog and Stilson Hutchin, 23 March 1903, P.O. Pedersen Archive.

[43] Charles Kingsley Fankhauser, born in 1866, was educated at Yale, graduating in 1893. While attending school he started one of the first trading stamp businesses in the United States. In 1900 he sold that business and moved to Boston, where he and others organized the Columbian National Life Insurance Company. In 1902 he sold his interest in that company and moved to New York, where he became a stock and bond broker. He was closely associated with American Telegraphone from 1905 to 1914. His activities after 1913 are largely unknown, but in 1925 he was engaged in the export of timber and lumber, with an office in New York. In 1948 he was still located in New York and was active in the export trade and also operated a tourist office.

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From this point onward, Aktieselskabet Telegrafonen and its small production company, Dansk Telegrafonfabrik, used the prospect of a new "Standard Telegraphone" from America as a justification for not proceeding with further development work.[44] The death of Lemvig Fog in May of 1906 served to confirm the Danish loss of interest in manufacturing telegraphones. He had always been the prime mover behind efforts at commercialization, and with him gone Danish investors put their hopes in Poulsen and Pedersen's increasingly successful work with wireless telegraphy. With respect to the telegraphone, all initiative now lay with the American Telegraphone Company.

The American Telegraphone Company

After Fankhauser made a cash payment in late 1905, the Danes transferred 325,000 shares of stock from the Telegraphone Corporation of Maine into the treasury of American Telegraphone. Those shares were then to be sold to finance the company's research and development efforts.[45] Fankhauser also bought six new recorders from the Danish company to use as demonstrators, and set about creating a viable company. He paid the company $1.67 per share (nominal value was $10.00 per share) and undertook to sell 275,000 shares. American Telegraphone's stockholder records have not survived, but other evidence suggests that Fankhauser might have sold as many as 230,700 shares between 1905 and 1907.[46] These sales provided the capital that allowed the company to set up a manufacturing plant and begin to develop a marketable product.

But at what kind of market should American Telegraphone try to aim its products? Selling the telegraphone as a telephone answer-

[44] Depositions by Valdemar Poulsen and Jacob Tesdorph, Court Hearing on the Extension of Patent, The High Court of Justice, Chancery Division, Public Record Office (London, 1913).

[45] Charles K. Fankhauser, *The Story of the Telegraphone* (Charles K. Fankhauser & Co., 1908), 7. This pamphlet was sent to shareholders by Fankhauser after the 1908 shareholders meeting. A copy is located in the records of the court case O'Reilly vs. American Telegraphone Company, Equity Cause 37690, Supreme Court of the District of Columbia (hereafter "Equity Cause"). These records are now in the National Archives in Washington, D.C.

[46] According to Fankhauser, he agreed to purchase 275,000 shares of the 350,000 in the company treasury (the other 150,000 shares of the company's 500,000 issued shares belonged to the Danish company through the Telegraphone Corporation of Maine). Fankhauser, 7.

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ing machine was unlikely to work, since years of unsuccessful work by the Danes and the Germans had shown that the technical problems to be overcome were considerable. Moreover, the Bell Telephone companies prohibited private equipment from being attached to their lines, which meant that, even if the technical problems could be overcome, the market was limited to non-Bell customers and private systems.[47] Clearly, developing a telephone answering machine was not the way to go.

American Telegraphone right from the start turned to another application: the telegraphone used as a dictating machine, the same application Aktieselskabet Telegrafonen in Denmark had finally arrived at. Since secretaries could use earphones during the transcription of recorded messages, the low volume of reproduction was less of a problem. In fact, there was a consensus among reporters at the 1900 Paris Exhibition that the sound quality of the telegraphone was far superior to that of the phonograph. Moreover, the rising interest in scientific management in the United States had led to the increasing use of dictating equipment by large corporations at this time. Business journals from this period reported favorably on the new phonograph dictating equipment, and it would have been clear to anyone involved in industry that the market for these machines was growing.[48] Thus, it is not surprising that the board of the American Telegraphone opted for developing a dictating machine, starting the development work from existing Danish prototypes. Throughout its years of operations, the primary focus of American Telegraphone's sales efforts was the dictating machine market.

As we have seen, Poulsen and his associates had produced two types of telegraphones at Dansk Telegrafonfabrik in Copenhagen. A reel-to-reel machine using piano wire as a recording medium had the advantage of a long recording time. By 1905, the prototype could record for up to 30 minutes. The wire was also cheap and easy to procure. However, the machine had to be kept in exact adjustment, or it would break or snarl its wire. The Danish wire machines were also extremely complicated mechanically; the ones available in 1905 contained over 1,000 parts.[49] Obviously, this made both manufacture and maintenance difficult.

The second type of machine, the disk recorder, had advantages and disadvantages that were mirror images of those of the wire

[47] Clark, "Suppressing Innovation: Bell Telephone and Magnetic Recording," 534–7.
[48] Millard, *Edison and the Business of Innovation*, 253-68.
[49] Fankhauser, *The Story of the Telegraphone*, 16.

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machine. The disk recorder was mechanically very simple, using a wind-up clockwork mechanism to rotate a thin steel disk for recording and playback, and it had far fewer parts than the wire machine. Because the disk was solid steel, there were no problems with breakage or snarling. And the disk could be easily mailed, which saved the cost of transcription. However, the disk machine did have notable disadvantages. The recording time for the five inch diameter disk was only forty-five seconds per side. Also, unlike wire, flat steel disks were not a common commodity and so would have to be specially manufactured, placing an additional burden on the company.

According to Fankhauser, he wanted in 1905 to give priority to developing a more practical version of the wire machine. In his view, the longer recording times that wire made possible outweighed the disadvantages of greater complexity. He thought that careful design and development could produce a far simpler machine (a view that would ultimately prove to be correct).[50] However, Harry S. Sands, who had been put in charge of the production because he had offered to produce the new telegraphone at his own factory in Wheeling, West Virginia, felt that the simplicity of the disk machine would enable the company to put that product on the market much faster.[51] Sands planned simply to scale up the diameter of the disk from 5 to 12 inches, which would permit increased recording time and result in a marketable product.[52] Sands convinced the board of directors that his approach was correct, and he was instructed to work exclusively on the disk machine.

Sands started work in January of 1906. By early February, he was confident that he would have a working prototype by the first of May. This estimate was to prove radically wrong, with disastrous consequences for the company. In fact, the first prototype was not finished until almost a year later. By May of 1908, when American Telegraphone was teetering on the edge of bankruptcy (in part because of the financial panic of 1907), only 40 more machines based on the prototype had been built, even though the board of

[50] Ibid., 17.

[51] Harry S. Sands (1864–1952) graduated from Cornell University as an electrical engineer and moved to Wheeling in 1894. He founded his company in 1896, and made a great deal of money electrifying coal mines in the area around Wheeling. He started Wheeling's first electric power company, and later brought in the area's first X-ray machine. He became a well-known figure in the community, and served on a number of corporate boards in the region. He purchased the Sands Crest farm just outside Wheeling in 1922, and devoted a great deal of time to experimental agriculture until his death.

[52] Fankhauser, *The Story of the Telegraphone*, 12.

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directors had authorized full-scale production the previous December. Without machines to sell, the company had no income. Without income, and lacking further funds, the company was forced to accept a friendly takeover, a move that effectively crippled the firm.

Why did Sands' development effort fail? Two problems were central. First, because the twelve-inch disk was much larger and heavier than the five-inch one, a more powerful motive force than a clockwork drive was needed. As a stopgap, a number of clockwork drive recorders were built with 10-inch disks, but these proved to be only a minimal improvement over the Danish machines in terms of recording time. An electric motor was substituted for the clockwork drive in the 12-inch unit, requiring considerable redesign. A major problem was that, unlike the clockwork drive, the electric motor generated electrical interference. After the interference problem was dealt with, a more serious one arose. The manufacture of 12-inch disks proved to be much more difficult than anticipated. In order for the steel to function properly as a magnetic recording medium, the disk had to be heat-treated after manufacture. The 12-inch disks, unlike their smaller counterparts, warped to a considerable extent during this treatment, rendering them unusable. After some experimentation, Sands determined that placing the disks under pressure from a press while they cooled prevented the warping, but this intermediate step raised the cost of manufacture and delayed production, since a suitable press had to be obtained.[53]

The disk machine Sands eventually developed was essentially unmarketable. It had a recording time of only two minutes per side, four minutes total per disk, and would have sold for $300. A contemporary phonograph could record for about the same length of time, and cost only $70.[54] Given the disk recorder's poor price-to-performance ratio, it is not surprising that no more than one hundred were ever built, and there is no evidence that any of them entered commercial service.[55]

[53] Ibid., 12–14.

[54] The Board of Directors set the price of $300 in February of 1908; they also authorized sales commissions of up to 33.3 percent for local sales agents. In April of that same year, the Board lowered the price to $150, but it is unclear if this was intended to be a retail or wholesale price, as no commissions are mentioned (Minutes of the American Telegraphone Company Board of Directors, 12 February 1908 and 16 April 1908, Equity Cause, hereafter "Minutes"). The phonograph price is from Millard, *Edison and the Business of Innovation*, 257.

[55] According to Harve Stuart, who worked for Sands, no more than 100 disk machines were built in the Wheeling factory. Stuart was unsure of the exact date of their manufacture, though it was after 1906. The machines would have been completed by 1910, since

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In May 1908 the company's problems finally reached crisis proportions. The board of American Telegraphone met and learned from their financial officer that the company had reached the end of its resources. Fankhauser introduced the board to Edwin Rood, then the president of the Hamilton Watch Company.[56] Rood made an oral offer to finance the company, and the board accepted. A major motivating factor was the well known success of Hamilton Watch.[57]

One month later, Rood sent a letter confirming his offer, on 9 July 1908, and the board decided to enter into a contract with him. The contract obligated Rood to purchase 94,300 shares of stock over the years from the company treasury for $2.00 per share (nominal value was $10.00 per share). In return for the discount on the stock price, Rood was to furnish his commercial expertise to the company and become general manager. The contract was signed on 30 July 1908, and Rood was elected president. He became general manager as well the following January.

Rood's takeover of the management of American Telegraphone fundamentally changed the company. His management style was completely different from that of the previous group of investors. In contrast to his predecessors, who had controlled the company by issuing orders based on decisions voted on at board meetings, Rood made decisions by himself. He did not even convene regular board meetings, a practice that led to the resignation of most of the surviving board members less than two years later.[58] Rood replaced them with board members he controlled. Subsequent meetings of the board became perfunctory affairs, in marked contrast to earlier prac-

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the Wheeling factory was closed and the machinery moved to Springfield, Massachusetts that year (Deposition of Harve R. Stuart, 16 November 1925, Equity Cause).

[56] Edwin Dexter Rood (1840–1935) was born in Ludlow, Massachusetts. He was first employed as a traveling salesman by a jewelry-importing firm in New York, beginning around 1866. He became a partner in the firm in the early 1870s. In 1877 he sold his interest in the jewelry business and purchased the Hampden Watch Company (formerly the New York Watch Company), a bankrupt manufacturing firm. He then moved the company to Canton, Ohio, and later purchased the Aurora Watch Factory. In 1893 he moved the machinery of both Hampden and Aurora to Lancaster, Pennsylvania, where it was consolidated with that of the Lancaster Watch Company to form the Hamilton Watch Company. Rood served as the president of Hamilton from 1893 to 1909, when he left that position to run the American Telegraphone Company. Rood continued to be involved with American Telegraphone as a major shareholder until his death, though he was removed from the presidency as a result of legal action in 1919.

[57] Minutes, 26 May 1908.

[58] Minutes, 21 January, 28 February, and 29 March 1910.

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tice.[59] Thus, from his election as president in mid-1908 to a court-ordered reorganization in early 1920, Rood effectively maintained sole control over American Telegraphone.

When Rood came to the American Telegraphone Company he was known and highly esteemed for his efficient management of Hamilton Watch. Rood had saved Hamilton from a threatening bankruptcy and turned it into a prosperous watch company at a time of falling prices and fierce competition. Rood's subsequent career at American Telegraphone was much less successful. Despite the development of products that had some market success, American Telegraphone lost money throughout Rood's term as president. Technically bankrupt in 1919, the company continued to exist after that date only because a lawsuit by shareholders put the firm under court supervision.

Why did the man who had been a successful manager at Hamilton Watch become ineffective as manager of American Telegraphone? Rood failed for two reasons. First, throughout his term in office, American Telegraphone suffered from a chronic shortage of capital. Second, and more importantly, Rood's management style, derived from his experience in the watchmaking industry, proved inappropriate for the development and manufacture of a technologically innovative product like the telegraphone. Taken together, these two factors explain American Telegraphone's inability to compete in the marketplace.

The chronic shortage of capital, present throughout the company's history except for a brief period during 1906 and 1907 when Fankhauser was having his greatest success at selling stock, derived from a number of factors. After placing his initial offering, Fankhauser was unable to continue selling shares at the same rate. One of the brokerage firms that he sold to, the Sterling Debenture Company, went out of business in 1907 after its owners were convicted of fraud. By late 1907, Fankhauser was in default on a number of agreements with American Telegraphone and he had to return a considerable amount of unsold stock. During that same year, an exposé in *Success Magazine* gave considerable publicity to

[59] An examination of the minute book of the corporation, preserved as part of the "Equity Cause" collection, shows this pattern clearly. Prior to Rood's takeover, meetings are regular, all board members are present, and there are extensive notes detailing the decisions made by the board. Notes for a single meeting often run for several pages. In contrast, under Rood's control, the meetings mandated by the bylaws of the corporation were skipped, there was often no discussion, notes are short, and only one or two of the board members actually attended.

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DEC 27 1906

An Unusual Opportunity For a Small Investment

HAD you invested only $100 in Bell Telephone stock a few years ago you could sell your interest to-day for more than $200,000. Such opportunities for fortune-making investments occur only once or twice in a lifetime, when some great practical discovery is made which, like the telephone, is susceptible of a "basic patent," securing to its owners an absolute and legitimate monopoly.

Such an opportunity is now open to the first few investors whose quick intelligence will enable

Sales literature from the Sterling Debenture Company, advertising American Telegraphone Company shares • Note the comparison with American Telephone and Telegraph shares. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

the risks associated with investing in radio companies.[60] It appears that this exposé also dampened the market for other high-technology firms such as American Telegraphone. Thus, by the time Rood joined the company, the stock market was no longer a reliable source of funds.

Rood had planned to use the money he had made while managing Hamilton Watch to provide development funds at American Telegraphone. In fact, it appears that the board of directors of American Telegraphone were as interested in Rood's money as in his management skill.[61] Unfortunately for the company, most of Rood's

[60] Tom Lewis, *Empire of the Air: the Men Who Made Radio* (New York, 1991), 80.

[61] Rood's contract with American Telegraphone called for him to purchase a certain amount of stock from the company within three years—a clause clearly designed to increase the firm's working capital. A copy of the contract is included in the Equity Cause papers.

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wealth was tied up in Hamilton Watch stock. His fellow shareholders bought Rood out over a period of years, so he never had access to his money in one lump sum.

The resulting capital shortage meant that American Telegraphone's workers had to make do with existing machinery and inventory. There were never sufficient funds at any one time to finance a comprehensive effort to improve manufacturing or quality. When Rood assumed control of American Telegraphone, he quickly decided that the disk machine was not a viable design. The telegraphone would never become a success unless it was able to beat the phonograph dictating machine in the market place. What was needed was a machine that could offer some feature existing phonographs did not have. Rood felt that the most logical one to offer was longer recording time. Consequently the development efforts had to start from the Danish wire machine, not the disk machine.

After abandoning the disk machine, Rood pursued a parallel strategy of internal and external development in trying to develop a viable wire recorder. Sands had done some work on the Danish wire telegraphone while he was developing the 12-inch disk model. Rood ordered the completion of a prototype, which he then demonstrated at the January 1909 stockholders meeting. The stockholders voted to abandon the disk machine and develop wire recording further. Rood then moved to purchase competing patents. Fankhauser's dissatisfaction with the disk machine had led him to fund research out of his own pocket. This research finally bore fruit in late 1908, when Fankhauser was ready to file a patent on an improved wire machine invented by his employed inventor, George S. Tiffany.[62] In March of 1909, Rood purchased Tiffany's patent for American Telegraphone for $7,500.[63]

Over the next three years, Rood funded work to improve the wire machine. Sands was no longer associated with the company after Rood replaced him as general manager in January of 1909, but Sands' assistant Harve Stuart continued to work for American Telegraphone until 1911.[64] Stuart carried out a series of development projects, primarily oriented toward simplifying the machine in

[62] United States Patent 1,142,384; filed 17 March 1909, granted 8 June 1915.

[63] Senate Committee on Patents, *A Bill to Renew and Extend Certain Letters Patent: Hearings on S-1301,* 72nd Cong., 1st sess., 10 March 1932, 18 (hereafter "Senate Hearing").

[64] The spelling Harve is correct—it appears on numerous documents in the Equity Cause records.

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order to ease manufacture. At the same time, Fankhauser continued to fund work by Tiffany. In February 1911, Rood conducted a comparison test between Stuart's latest design and a new machine developed by Fankhauser and Tiffany. Although Stuart's machine had more features, such as a dial indicator for the amount of wire left on a reel, the Fankhauser-Tiffany machine had superior sound quality and was much cheaper to manufacture.[65] Stuart resigned from American Telegraphone soon after the test, and Rood purchased the rights to the improved Fankhauser machine. All factory machinery had been moved from West Virginia to Springfield, Massachusetts in late 1910. After Rood hired a new factory foreman in October, preparations were made to start production of Tiffany's design.[66] However, continued efforts to improve the machine delayed output until 1912.

Production was begun to supply the needs of the Telegraphone Sales Company, an independent marketing firm set up the year before. The Telegraphone Sales Company had been founded at the urging of Fankhauser by the McCrillis family, who had made their money in the wholesale flour business. Arthur McCrillis, son of the flour business's founder, entered into a contract with Rood to buy the output of the Springfield factory and to set up a series of sales offices in major cities.[67] McCrillis pressured Rood to go into production, and even paid for some of the necessary tooling for the factory (a clear indication of Rood's money problems). The first commercial wire telegraphones built in the United States left the factory in August 1912.[68]

McCrillis was initially successful in selling these machines. Around one hundred telegraphones were purchased by various firms. The single largest sale was to the Du Pont Company, which bought 20 machines initially and almost 30 more over the next two years. Their machines, first installed in 1913, included a telephone network, which allowed executives in their offices to call up a central switchboard and record dictation for later transcription. The company was initially happy with the system, but stopped using it in 1917 and scrapped it in 1919, largely because of continual break-

[65] Stuart Deposition, 16 November 1925, Equity Cause.

[66] The new foreman was Mr. E. F. Creager of Lancaster, Pennsylvania, who had managed the Hubley Toy Factory for the previous fourteen years (Minutes, 20 October 1910).

[67] Senate Hearing, 21.

[68] Ibid.

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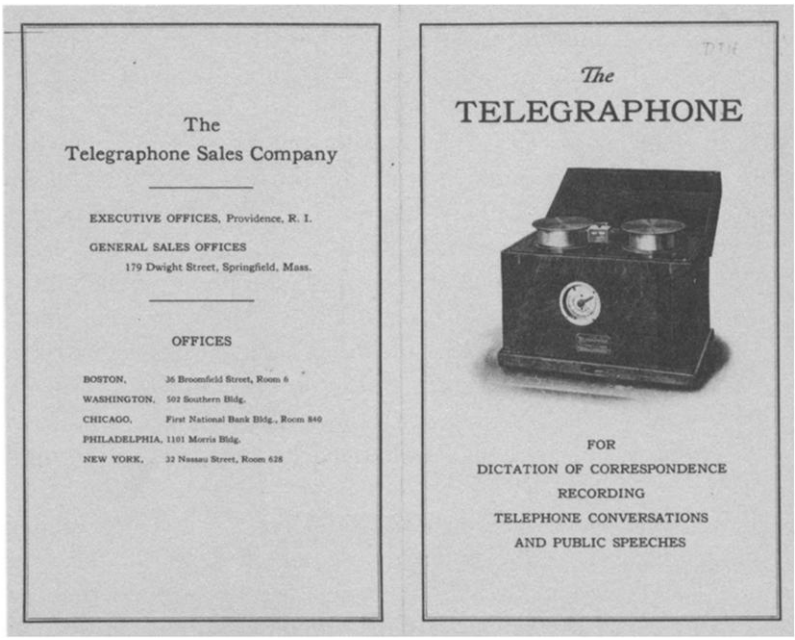

Sales brochure from the Telegraphone Sales Company, showing the final version of the American Telegraphone wire recorder, which was sold to Du Pont and other customers • The wire speed was 2 m/s; recording time was roughly 30 minutes maximum. The dial on the front of the machine indicates total recording time. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

downs and the difficulty in getting replacement parts.[69] Du Pont even hired one of American Telegraphone's technicians to work full time at the site doing maintenance and repair, but even his efforts were unable to keep the system running.[70] Similar complaints dogged the other machines McCrillis sold, and he was out of business by 1915.

Although Rood and his predecessors at American Telegraphone had spent close to half a million dollars between 1905 and 1912, the money was not sufficient to develop a machine that worked effectively. Stuart, though apparently a competent technician, lacked comprehensive engineering training and was not a talented inventor. It appears that Rood continued to employ Stuart simply because he could not afford anyone better, given his shortage of funds. Rood then purchased the design that Fankhauser and Tiffany had pro-

[69] Ibid.; James S. Grant to H. L. Washburn, 15 Jan. 1919, "Exhibits" folder, Equity Cause.

[70] Correspondence between American Telegraphone and Du Pont, Folder labeled "Depositions," Equity Cause.

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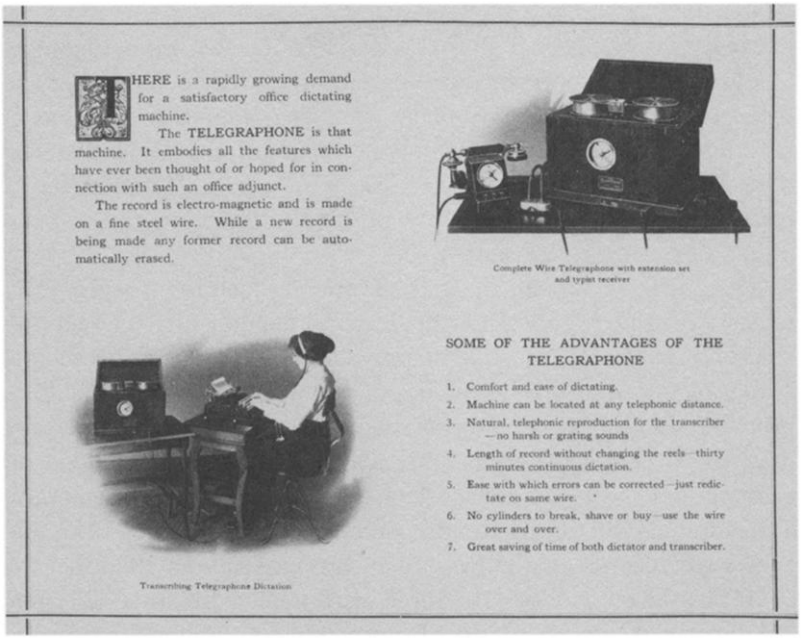
THERE is a rapidly growing demand for a satisfactory office dictating machine.
The TELEGRAPHONE is that machine. It embodies all the features which have ever been thought of or hoped for in connection with such an office adjunct.
The record is electro-magnetic and is made on a fine steel wire. While a new record is being made any former record can be automatically erased.
Complete Wire Telegraphone with extension set and typist receiver
SOME OF THE ADVANTAGES OF THE TELEGRAPHONE
1. Comfort and ease of dictating.
2. Machine can be located at any telephonic distance.
3. Natural, telephonic reproduction for the transcriber —no harsh or grating sounds
4. Length of record without changing the reels—thirty minutes continuous dictation.
5. Ease with which errors can be corrected—just redictate on same wire.
6. No cylinders to break, shave or buy—use the wire over and over.
7. Great saving of time of both dictator and transcriber.
Transcribing Telegraphone Dictation

American Telegraphone wire recorder set up for office dictation • The telephone handset, seen on the left in the upper picture, is used for recording. The three buttons on the telephone are a remote control (forward, stop, and reverse). The dial on the telephone is linked to the dial on the machine, and indicates total recording time. The foot control and headset, seen in the lower picture, were used by the typist during playback. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.)

duced, but it proved to be little better than Stuart's. The ultimate result was clear—the machine design that Rood approved was not competitive in the marketplace. Even after all the years of development work done by Rood and his staff, the receiver who ran the company after 1920 estimated that it would take an additional half million dollars to design, manufacture and distribute a competitive product.[71]

But poor design due to lack of funds was only part of the problem. Although capital shortages during development account for some of the difficulty, poor management was the real issue. Surviving company documents contain some references to design flaws, but the majority of failures in the field came from poor quality control. The complexity of the telegraphone mechanism, which had to be both reliable and easy to operate, increased the problems the firm had, because any failure of any part of the machine led to its malfunction. Although prototypes performed well, actual production

[71] Receivers Report, March 1921, Equity Cause.

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machines broke down at an unacceptable rate. The competing technology of the wax-cylinder dictating machine was much cheaper and more reliable, and the advantage the telegraphone had of longer recording time and of easy telephone hookup for centralized dictation did not compensate for its basic unreliability. Without careful control by management, quality problems destroyed the telegraphone's chances in the marketplace.

Surviving documents indicate that Rood's factory manager, E. F. Creager, had no experience with electrical manufacture (he had previously run a toy factory), and he proved unable to set up the telegraphone factory on an efficient basis. He was consistently unable to produce machines on time or of adequate quality. But Rood did not draw the logical conclusion: fire Creager. He also compounded his error by not having in place adequate financial controls. American Telegraphone did not use double-entry bookkeeping until 1917, and even what records existed were in such poor shape in 1920 that the court's receiver had to hire three accountants full time for nine months to put them in order.[72] Rood actually ran American Telegraphone out of his personal checkbook for several years, failing to separate out his personal affairs from those of the company. Given the difficulty the court had in sorting out the affairs of the company after it was taken over, it is unlikely that Rood ever had a very clear idea of what was going on.

All of these management problems stemmed from Rood's prior experience at the Hamilton Watch Company, which established Rood's particular technological frame of meaning. According to Michael C. Harrold, a historian of the American watch industry, the success of a watch manufacturing company in the United States in the late 19th century was dependent not on the technological skill of its management but rather the financial and marketing skill.[73] Rood's success at Hamilton Watch was based on his ability to raise money and deal with the purchasers of watches. His lack of technical skill was not a handicap in the watchmaking field, where a body of knowledge existed and experienced watchmakers could be easily hired. The telegraphone, on the other hand, was a new technology and could not be managed in the same way. American Telegraphone's

[72] Ibid.

[73] Michael C. Harrold, "American Watchmaking: A Technical History of the American Watch Industry, 1850–1930," a supplement to *The Bulletin of the National Association of Watch and Clock Collectors*, 14 (Spring 1984). The account of American watchmaking management methods below is drawn from this work.

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competitors, the Dictaphone and Ediphone companies, paid close attention to both manufacturing and marketing their phonograph dictating equipment, changing their machines to make them easier to use and more reliable.[74] American Telegraphone would have had to match that performance if it wanted to compete. Rood's management style proved unequal to the challenge.

The Du Pont debacle made trying to obtain sales increasingly difficult. By 1917, the company's only customer was the United States Navy, which wanted to use telegraphones for recording high-speed wireless telegraphy signals. Telegraphones had been used for that purpose as early as 1911 by the Federal Wireless Telegraph System in California, but the Navy was unaware of this potential application until 1916, when it was discovered that a German-owned radio station in Patterson, New Jersey, was using a speeded-up telegraphone to send intelligence information to German submarines operating in the Atlantic. Recording on a telegraphone and then speeding it up for transmission resulted in a signal that emerged as an indecipherable whine, that could only be decoded by recording at high speed at the receiving end and then slowing down the recording. The Germans used telegraphones purchased prior to the war from American Telegraphone through Poulsen's Danish company.[75] After the U.S. government seized the German station, the Navy asked Rood about the equipment found there. Rood replied that the high speed unit was a regular production item, and that American Telegraphone could supply the Navy with a limited number of machines immediately.[76] The Navy eventually purchased fourteen telegraphones, ten of which were of the high-speed type that could both send and receive. The remaining four were normal-speed machines that were used for transcription work only. This is the only known sales contract for American Telegraphone between 1915 and 1920 involving telegraphones.

Despite the failure to sell more, American Telegraphone sur-

[74] Millard, *Edison and the Business of Innovation*, 258–267.

[75] At least six machines were sold in 1914 to the German government; it is unknown if the German Navy had additional machines built or if more than six machines were purchased before the war. A German submarine that visited the United States in mid-1914 was observed to have a telegraphone on board by those given tours of the ship, but it appears that this did not spark the American Navy's interest at that time. Senate Hearing, 24.

[76] Edwin Rood to Lt. M. Paternot of the U. S. Radio Station, Sayville, Long Island, New York, 18 July 1917, Equity Cause.

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vived by becoming a subcontractor for precision machine work.[77] During World War I, the company made shell extractors, machine-gun parts, and universal joints, as well as a number of other components for the armaments industry. Even with war work, however, the company was floundering under a large debt load. In February of 1918, the board voted to liquidate the company, and Rood was authorized to try to find a buyer.[78] When no takers emerged, the board voted in March 1918 to enter receivership.[79] The company was in the process of trying to sell off its assets when a suit against it was brought in the District of Columbia by a number of shareholders alleging mismanagement and conspiracy to defraud.[80] The court froze the company's assets and appointed its own receiver to manage the company.

American Telegraphone never left receivership and was essentially moribund after 1927. The court case dragged on through the 1920s, until all of the company's patents ran out in 1933. At first the company continued to market telegraphones (about forty machines were sold between 1920 and 1924), mostly to large corporations interested in magnetic recording due to the pending expiration of Poulsen's basic patents. No improvements were made in the design of the machines built during this period, and there was no funding for research. By 1922, telegraphone orders were supplied by assembling parts from stock on hand; almost no new parts were being made. The company kept its doors open until 1934 by making universal joints under contract, but the factory closed down when that business dried up. American Telegraphone's assets were eventually

[77] Due to the lack of surviving records, the exact number of machines sold is unknown. Prior to 1920, roughly one hundred wire machines were sold to the McCrillis organization, and fourteen more to the American Navy. Six were sold to the German Navy, but it is unclear if these are separate or should be included in the McCrillis total. After American Telegraphone went bankrupt in 1920, approximately forty-five other machines were sold while the firm operated under a court-appointed receiver. Thus, it appears that the firm sold no more than 170 machines total. The actual total is probably less, since it is known that the company refurbished returned machines returned and resold them. Of these, only six survive in various museum collections and in private hands. All of the serial numbers on the surviving machines are in the 900s, but other evidence suggests that the leading 9 was a model designation rather than a reflection of the overall production.

The total number of wire machines manufactured was probably not much more than this, if one includes prototypes and machines used by the company itself. The firm also built between 40 and 100 of the disk machines designed while H. S. Sands was in charge. It appears none of these machines were sold to the public, and none are known to survive.

[78] Minutes, 26 Feb. 1918.

[79] Minutes, 11 March 1918.

[80] This suit is the one referred to in note 43 as "Equity Cause."

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acquired in 1935 by the Curtis Universal Joint Company, which sold the remaining inventory of telegraphone parts for scrap.[81] Stockholders continued their lawsuit against Rood until the mid-1930s and even tried to get Congress to extend the company's patents, but to no avail.[82] When the last patent expired in late 1933, the company ceased to control any marketable assets and was inactive until the formality of its court-ordered dissolution in 1944.

Conclusion

There is no doubt that Valdemar Poulsen in 1898 was inspired to invent the telegraphone by what he considered to be a problem, a "presumptive anomaly," in the telephone system.[83] He, like the rest of the technicians in Aktieselskabet Telegrafonen, had been socialized into a telephone frame of meaning that made them give low priority to potential applications of the telegraphone other than those directly coupled to the rapidly expanding telephone system. The telephone frame of meaning is clearly recognizable in the introduction to Poulsen's main patent description from 1898; it is essential to Hagemann's amplification idea, it is the rationale behind all the development work at Mix & Genest (1900), Siemens & Halske (1901-02), and by Hagemann and Christensen during the Danish delegation's visit to the United States in the spring of 1901. In the first four years after the invention in 1898 almost all development efforts were focused on using the telegraphone within the telephone network.

But there is nothing strange in this. The telephone was the high-tech growth industry at the turn of the century, much like the telegraph had been three and four decades earlier. The telephone was easy to use by everybody, yet its function depended upon mysterious electric and magnetic laws of nature far beyond the intellectual capabilities of the average person. In spite of this (or perhaps because of this) the telephone attracted the attention of many hopeful inventors of the day—but also of many business people and investors who had little difficulty in recognizing the smell of profit in

[81] R. E. Curtis to Dr. Alexander M. Pontiatoff, 28 April 1960, box 14, Ampex Archives, Ampex Museum, Redwood City, California.

[82] Senate Hearing, 10–43.

[83] The term "presumptive anomaly" is defined in Edward Constant, "A Model for Technological Change Applied to the Turbojet Revolution," *Technology & Culture* 14, no. 1 (1973): 553–9.

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the rapidly expanding telephone system. The business people in the board of Aktieselskabet Telegrafonen never doubted that potential collaborators should be sought among big companies with expertise on the manufacturing and marketing of telephone equipment—such firms as Mix & Genest, Siemens & Halske, and the Bell Telephone Company. And they were only strengthened in their opinion by the extremely positive reception of the telegraphone in 1900 at the Paris Exhibition, where the intimate connection of the telephone and the telegraphone was stressed over and over again.

Having concentrated all its efforts on developing a cheap and reliable telephone answering machine in accordance with its telephone-dominated world view, the Danish-inspired European network set up to exploit Poulsen's invention quickly faded away when that objective proved impossible. Even the main Danish experts, Poulsen and Pedersen, gave up and switched to another project that looked more promising—wireless telegraphy and telephony. As a result of the failure of the telephone frame of meaning, compounded by the difficulties of developing a new advanced technology from a peripheral country, after 1904-1905 there were no more serious Danish attempts to commercialize the telegraphone.

But why did Edwin Rood, American Telegraphone's director and general manager through many years, then not succeed with his efforts to develop and market a wire telegraphone? His machine was, after all, designed for use in an apparently more easily accessible market: Dictaphones for use in the administrative departments of public and private business.

Rood failed because he managed American Telegraphone in much the same way he had run Hamilton Watch. Lacking technological skill himself, he hired workmen and expected them to take care of the technical problems and run the production line while he took care of financial matters. Unfortunately for Rood, one could not hire a "telegraphone maker" in the same way one could hire a watchmaker. The telegraphone was a new high-tech technology item, still lacking its own experts. Rood's management style, well suited for the watch business, was insufficient to the demands of the telegraphone.

The sad fate of the telegraphone is intimately related to its early proponents' understanding of telegraphone technology and its proper place in the modern society. Valdemar Poulsen and his fellow Danes foresaw a brilliant future for the telegraphone as a new and potent component in the rapidly growing telephone system. But as the road to the promised land seemed blocked by almost insur-

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mountable difficulties, they quickly gave up and left it to the Americans to develop a "standard telegraphone." Edwin Rood saw the telegraphone as a new and advanced dictating machine, able to compete effectively with the phonograph in the business administration market. Rood's strategy was basically sound but his unrecognized problem was that he regarded the telegraphone as a machine to be produced and marketed like any other standard commodity, rather than a new technology to be nurtured. Trapped within their visions of this new technology, the frames of meaning they brought with them to the new technology, neither group was successful.

In a larger context, the concept of frames of meaning has potential for wider application in the study of the problem of the development and transfer of organizational capabilities. Alfred D. Chandler, Jr. has pointed out the success of firms with narrow market focus that are able to take advantage of the product-specific skills and experience of their employees to enter new markets. Chandler admits, however, that not all firms were able to make use of these advantages, citing the failure of British firms in the chemical, electrical and metalworking fields as examples.[84] Similarly, William Lazonick has pointed out the importance of "social determinants of technological change," arguing that the interaction of organization and technology determines the long-term potential for competitive success of a firm. He leaves open the question of exactly how this interaction takes place.[85] The idea of frames of meaning provides one potential tool for exploring these issues. By examining the outlook and mindset of participants, the frames of meaning they bring to business decisions about technology, it is possible for scholars to develop a clearer picture of the reasoning behind those decisions, and to explain developments that otherwise appear irrational. We encourage others to make use of this approach, and we hope they find the technique as useful as we have.

[84] Alfred D. Chandler Jr., "Learning and Technological Change: The Perspective from Business History" in Thomson, ed., *Learning and Technological Change*, 24–39.

[85] Lazonick, *Business Organization and the Myth of the Market Economy*, 195.

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Business History Review

SPRING 1995

THE "TELEGRAPHONE," PARIS EXHIBITION, 1900

Published by the Harvard Business School

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Front Cover: Danish Pavilion
at the Paris Exhibition, 1900

"Crossed Wires and Missing Connections: Valdemar Poulsen, The American Telegraphone Company, and the Failure to Commercialize Magnetic Recording." The telegraphone was demonstrated in the small booth just behind the woman in the center of the picture. (Photograph reproduced courtesy of the Peder O. Pedersen Archive.) See pp. 1–41.

Back Cover: Burlington's Wartime Production

Circulated during World War II, this flyer described the variety of goods produced by Burlington Mills for military customers. Despite its claims, the war did not lead to great increases in company earnings. Burlington's period of greatest growth and profits came after the war, when it could again secure enough rayon yarn to expand its capacity. (Photograph reproduced courtesy of the Southern Historical Collection.)

For an article on Spencer Love and Burlington Mills, see pp. 42–79.

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ISSN 0007–6805

Second-class postage paid at Boston, Mass.

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